psychology. A's concepts, memories, and so on are seen relative to a participant B and a conversational domain R; moreover, relative to the standard, though liberal, conditions that are maintained by B (either the CET heuristic or an interviewing role).

Because of that, the cognitive reflector has a family resemblance to the steady state technique (Chapter 1 and Chapter 2) and there is a specific identification that exhibits limitations of this technique; roughly, the SST is a reflector for one relation R_i assumed to be independent of others in R and the impoverished conversation that does take place has but one sprout and one occasion.

Chapter 6. Strict Conversations, Heuristics, and Classes of Experiment

In this chapter we describe the forms of strict conversations which take place under the CET heuristic (Section 1) and the uncertainty regulation heuristic (Section 2) in the CASTE facility. It would be possible to introduce the evolutionary heuristics, employed in the course assembly mode of operation at this stage. But, on balance, it is better to discuss the development of a conversational domain (when R is rewritten as R(n)) after detailing the structure of R and describing a verbally administered heuristic for generating a conversational domain. These topics form the subject matter of Chapter 7 and the evolutionary or course assembly heuristic is thus presented in Chapter 8.

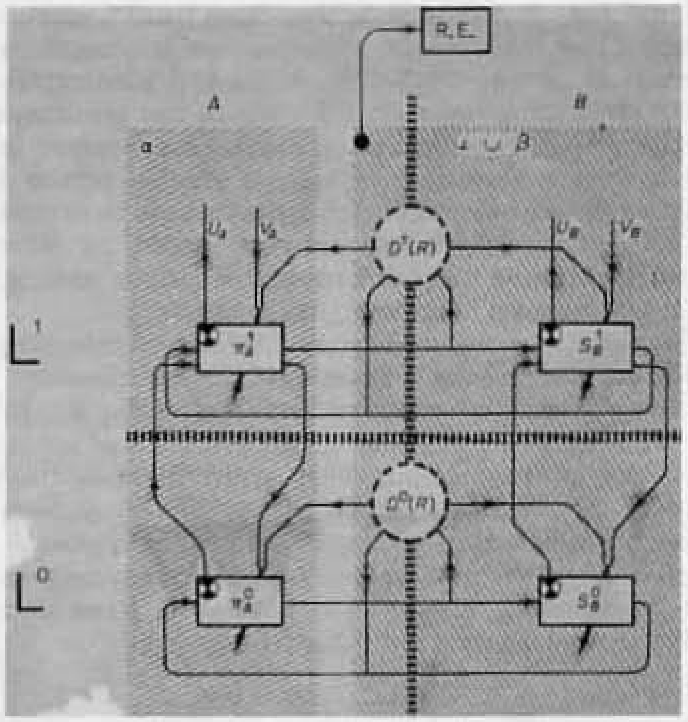
Paradigms for various well known experimental situations are derived by imposing appropriate restrictions upon CASTE transactions. Thereby these experimental situations can be imaged, as strict conversations, within the facility. In practice, most experiments are not strict conversations but it is argued that the canons of good and informative experimentation lead the experimenter to approximate a strict conversation as closely as possible. Section 3 is an account of those experimental paradigms that can be derived from the CET and the uncertainty regulation modes; the other paradigms are described in Chapter 9 (general modelling, gaming, and game like interpersonal interaction) and in Chapter 11.

Finally, Section 3 goes slightly beyond this brief by presenting paradigms for the experimental situations of "personal construct" psychology (the elicitation of constructs, laddering, and so on). By this means, we introduce predication and operations that act on $D^1(R)$ or $D^0(R)$ as they are inscribed at the interface (thus replacing $D^1(R)$ by $D^1(R(n))$ and $D^0(R)$ by $D^0(R(n))$. Such domain-extending (predicating) operations are practically possible (repertory grids are widely used) and are essential in the argument of Chapter 7. However, they are not justified in terms of a mechanically executed heuristic until Chapter 8.

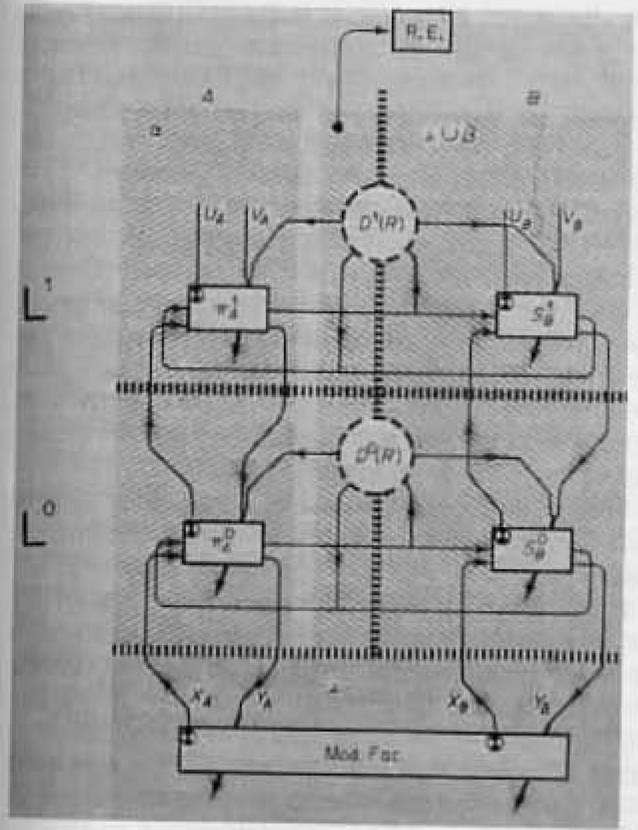
Icon 8 shows the embodiment of CASTE programmed so that B is a CET heuristic or support to A in the conversational domain of any fixed subject matter $D(R) = \langle D^1(R), D^0(R)\rangle$. Icon 8 is extended in Icon 9 to include a modelling facility and its connections; for example, STATLAB.

These icons are used to represent the "cognitive reflector" (CET) construction of Chapter 5 and the conversational process in Chapter 4; in Section 2 a slight extension of Icon 9 is used to represent the uncertainty regulation heuristic of Chapter 4, Section 7. For each purpose, the icons are augmented by pithy statements bearing on different aspects of the process. The following comments, (a) to (i), though repetitious, render these aphorisms more readable.

(a) In Icon 8 both A and B have access to an inscription of $D^1(R)$ at the interface (the entailment structure, ES(R), of



Icon 8.



Icon 9.

Chapter 4). At level L^1 this serves as a modelling facility on which A and B can imprint values of marker predicates (or sequences or sets of values) thereby drawing pictures. Such pictures are drawn when A executes $\underline{\mathrm{Proc}_A^1}$ i or B executes $\underline{\mathrm{Proc}_B^1}$ i.

(b) If obeyed, either $\underline{\mathrm{Comm}_A^1}$ i or $\underline{\mathrm{EQuest}_A^1}$ i leads to the execution of $\underline{\mathrm{Proc}_A^1}$ i; similarly, either $\underline{\mathrm{Comm}_B^1}$ i or $\underline{\mathrm{EQuest}_B^1}$ i leads to the execution of $\underline{\mathrm{Proc}_B^1}$ i.

(c) $\underline{\mathrm{Proc}_A^1}$ i belongs to π_A^1 and is applied to some $\underline{\mathrm{Proc}_A^0}$ i in π_A^0 wholly or partly embodied in α.

Since B is a CET heuristic, $\underline{\mathrm{Proc}_B^1}$ i is part of the operator data base (Chapter 4) and is applied to a copy of the entailment structure retained in processor β (a structure representing all legal configurations of the $\underline{\mathrm{Proc}^0}$).

(d) If A obeys $\underline{\mathrm{Comm}^1_A}$ i he constructs (wholly or partly in α) some procedure Proc^0_A i; similarly if A obeys $\underline{\mathrm{EQuest}^1_A}$ i he explains the generation $\overline{\text{of } \mathrm{Proc}^0_A}$ i by executing $\underline{\mathrm{Proc}^1_A}$ i and drawing a picture or description of the process at the interface. The L^1 transactions are used as the "drawing instrument" and are designed so that any transaction sequence leaves a "picture".

(e) If B obeyed $\underline{\mathrm{Comm}^1_B}$ i quite literally, the CET heuristic would reassemble (in all legal ways) the task structure $TS(R_i)$. Since the task structures exist (appendix E) the operation is superfluous, but a record of the computation routines that would have been mustered is retained. If B obeys $\underline{\mathrm{EQuest}^1_B}$ i the record in question is output and displayed at the $\overline{\text{interface}}$ as an advice giving picture representing the derivation. Since the execution of $\underline{\mathrm{Proc}^1_B}$ i is a dummy activity (it is not dummy in the course assembly mode of Chapter 8) π^1_B is replaced by S^1_B.

(f) In Icon 9 both A and B have access to a modelling facility such as STATLAB (analogous, at level L^0, to the L^1 inscription, ES(R), on the interface).

(g) $\underline{\mathrm{Proc}^0_A}$ i is in π^0_A. $\underline{\mathrm{Proc}^0_B}$ i is in B's repertoire. Since B is a CET heuristic (not a P individual in its own right) $\underline{\mathrm{Proc}^0_A}$ i is the executable form of $D^0(R_i)$; namely, $TS(R_i)$, and is fixed. Hence the repertoire is S^0_B rather than π^0_B.

(h) If A obeys $\underline{\mathrm{Comm}^0_A}$ i he represents $\underline{\mathrm{Proc}^0_A}$ i as a representative serial model ($\underline{\mathrm{Proc}^0_A}$ ij, say) in the modelling facility; if executed under the τ clock, this model brings about and satisfies R_i. If A obeys $\underline{\mathrm{Exec}^0_A}$ i he describes this model as an explanation.

(i) If B obeys $\underline{\mathrm{Comm}^0_B}$ i then (since B is a CET heuristic) B may copy some or all of $TS(R_i)$ into the modelling facility as a demonstration which, executed under the τ clock, also brings about R_i. Whether the demonstration is given or not, $TS(R_i)$ still exists, stored in β. Hence, its execution can be matched to A's model. In particular, the models can be matched as securing the same relation; if they do match, then (since $\underline{\mathrm{Proc}^0_A}$ ij and $\underline{\mathrm{Proc}^0_B}$ ij described by $D^0(R_i)$ secures R_i) the relation is R_i.

1.1. *A Statements.* Participant A (the student in "CASTE") is not allowed to make *direct* commands or ask direct questions of B; nor can he give (attention directing) commands to himself or ask himself (introspective) questions; these superficially restrictive conditions not only buttress the position of B as a valid support in a strict conversation but also avoid the type of self-reference noted in Chapter 5, Section 2.2.2.1. At first sight, the conditions are implausibly cramping but the appearance is illusory since, in return for accepting them, A is permitted to ostend any topic relation he likes by transactions which say that he desires to receive at level L^1 a $\underline{\mathrm{Comm}^1_A}$ i, $\underline{\mathrm{EQuest}^1_A}$ i or at level L^0 that he desires to receive a $\underline{\mathrm{Comm}^0_A}$ i, $\underline{\mathrm{EQuest}^0_A}$ i. Since the CET heuristic satisfies any legal desire by issuing a $\underline{\mathrm{Comm}}$, $\underline{\mathrm{EQuest}}$, it follows that A is free to entertain any (legal) $\overline{\text{intention he}}$ likes and is subject only to the initial restraint that he sees the conversational domain in any one of the many ways permitted by $D(R) = \langle D^1(R), D^0(R) \rangle$ (perhaps, as later, indefinitely many ways; in any case the limitation is insignificant unless A has already learned the subject matter when, (Chapter 4) the CET heuristic rejects him for the role of participant). Actually, the main restriction is that A must always express his intention[14].

A can develop and rationalise his grounds for harbouring an intention because he may always engage in exploration (Table 1 of Chapter 4 or Section 1.7.12 of Chapter 5). If A ostends any node, he does so by citing a sufficient number of L^1 descriptor values to identify it uniquely; for example, A may dial $\langle F, 5, \phi \rangle$ which satisfies this condition. He does not point at the L^* index of the node (a value of i) like an external observer. A node is validly ostended under the explore transaction if A has cited sufficient L^1 descriptor values to identify it as node "i" in L^*. In this case A receives all other L^1 descriptor values that are relevant to node i. By using the explore transaction, A is able to build up a redundant L^1 description $D^1_A(R)$ of R; of "what may be known".

As it stands, the CASTE equipment supplies relevant values on all of the L^1 descriptors in $D^1(R_i)$. But (Chapter 5, Section 1.7.12) the description $D^1(R)$ is (usually) one of a family of descriptions and this particular family is one of several. The CASTE equipment under current development, which is outlined in the context of descriptor families in Chapter 7, will permit A to explore descriptions of the conversational domain belonging to many families (in addition to the values of the L^1 descriptors in one currently exhibited family). For this purpose, it is necessary

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[14] The facility was originally designed with very elaborate contrivances to make certain that A did always do so; perhaps because I was unconvinced by my own theory. As it turns out, these arrangements have never been used. People become entrained by the system as they, theoretically, should be.

to "write" the graphical display on the face of a storage tube, to delete one display and call for others dynamically.

By either method (existing or under development) A is said to appreciate the topic relation, R_i, of node i if he can give an L^1 description $D^1_A(R_i)$ and (as below) the CET heuristic requires that any aim node is appreciated.

1.1.1. The L^1 statement of desire or intent is *Aim* and for any occasion an aim must be specified. As a convention, on occasion n, A aims for node f. An aim is legal if node f is not marked as understood. In general, several aim nodes can be accommodated, (say $f \in F$). So that aim may elicit (from B) either an unqualified or a qualified $\underline{Comm}^1_A$ f, $\underline{EQuest}^1_A$ f. In this account one and only one aim is assumed to exist for each occasion.

The L^0 statement of desire or intent is *Goal* (the indices of one or more topic relation that A intends to learn about). As a convention, the indexed components of goal are $<$node $g_1, \ldots$ node $g_c >$. Any component g_p; $p = 1, \ldots c$; is legal if node g_p is not marked as being understood and if node g_p is a member of Ent Set f (Chapter 5, Section 1.7.12). If aim is specified (as it must be on any occasion) then at least one goal must also be specified.

Any legal goal node either belongs to workset (the collection of nodes from which tutorial data is directly accessible) or it is a candidate for inclusion in workset. In fact, node g_p will become a member of workset if all the nodes in at least one Im Ent Set k_p are marked as being understood.

As a convention the nodes of workset are indexed $i_1 \ldots i_c$. Either $g_p = i_p$ or, if not, a routine called *TagAim* is executed by B. Any $g_p \neq i_p$ is marked as a subsidiary aim node beneath which there are subsidiary goals which may have subsidiary aims, etc. Subsidiary goals are TagAim l, $< Z >$ where l is a depth index and $< z >$ is a nested set of index lists (the routine is best explicated by scrutiny of Appendix D); Aim = TagAim, 0, $<$ Void $>$.

Instead of pursuing TagAim, A may delete any $g_p \neq i_p$ and/or add further goal components, provided that there is at least one goal component on any occasion.

Ultimately, the nodes in workset satisfy the condition that for any i there is at least one k for which all nodes $j_{l_k} \ldots j_{m_k}$ in Im Ent Set k,i are marked understood.

Examination of Appendix D shows that Workset may be

bounded (by nodes $j_{l_k} \ldots j_{m_k}$ in Im Ent Set k,i) in either of two different ways; namely

(a) Node j_r; $r = l_k \ldots m_k$; is already marked as understood due to an initial condition or because the sprout of the A, B, conversation rested on $i = j_r$ upon some previous occasion when correct understanding was reached.

(b) Node j_r is correctly understood as part of the TagAim routine; A opts to explain, rather than Aim for j_r during TagAim; A is required, in that case, to correctly explain j_r itself and having done so to correctly explain, for at least one k_{j_r}, each member of Im Ent Set k_{j_r}. The pair of explanations thus elicited constitute a correct understanding (obtained by a reversal of the usual precedence).

The qualified L^0 statement of desire or intent is *Subgoal* which is legal for any node $i_p = g_p$ in workset (consequently a node originally intended as a component of goal).

1.2. *B Statements.* If B is a CET heuristic, Participant B interprets and acts upon any legal statement of intent as follows.

Aim f $\rightarrow$ $\underline{Comm}^1_A$ f, $\underline{EQuest}^1_A$ f and $\underline{Comm}^1_B$ f, $\underline{EQuest}^1_B$ f

and $\underline{Comm}^0_B$ f, $\underline{EQuest}^0_B$ f (or the unqualified

form for $f \in F$, with several aim nodes).

Goal G = $< g_1 \ldots g_c > \rightarrow$ Workset $< i_1 \ldots i_c >$

(through TagAim).

Workset G $\rightarrow$ $\underline{Comm}^0_A$ G, $\underline{EQuest}^0_A$ G and

$\underline{Comm}^1_B$ G, $\underline{EQuest}^1_B$ G

Subgoal i $\rightarrow$ $\underline{Comm}^0_A$ i, $\underline{EQuest}^0_A$ i and

$\underline{Comm}^0_B$ i, $\underline{EQuest}^0_B$ i.

1.3. *Operation.*

1.3.1. From Chapter 5, Section 1.7.12, there is a head node (or set of nodes) in any conversational domain R, which entails all R_i in R.

1.3.2. At occasion $n = 0$, B addresses A with $\underline{\mathrm{Comm}}^0_A$ (Head), $\underline{\mathrm{EQuest}}^0_A$ (Head).

1.3.3. This initial command/question is the L representation of an experimental contract (Chapter 5, Section 1.2 and Section 2.1) in a conversational object language L with the interpretation of Chapter 5, Section 2.5.

1.3.4. Unless A has learned the domain, A interprets $\underline{\mathrm{Comm}}^0_A$ (Head), $\underline{\mathrm{EQuest}}^0_A$(Head) as $\underline{\mathrm{Comm}}^1_A$(Head), $\underline{\mathrm{Equest}}^1_A$(Head) and ostends aim and goal (since an occasion has commenced). If aim = goal = f then A receives $\underline{\mathrm{Comm}}^0_A$ f, $\underline{\mathrm{EQuest}}^0_A$ f; if not $\underline{\mathrm{Comm}}^1_A$ f, $\underline{\mathrm{EQuest}}^1_A$ f and (for goal G in workset) A receives $\underline{\mathrm{Comm}}^0_A$ G, $\underline{\mathrm{Equest}}^0_A$ G which may be qualified (by subgoal i) to $\underline{\mathrm{Comm}}^0_A$ i,G; $\underline{\mathrm{EQuest}}^0_A$ i,G. As A obeys/answers these commands/questions with models or explanations the selections furnish a partial explanation in reply to $\underline{\mathrm{EQuest}}^1_A$ i (Head) of which the segment of the nth occasion is $\underline{\mathrm{Expl}}^1_A\, i_n$ and is (by legality) one of many possible correct replies implied by $D^1(R_{i_n}) \equiv \underline{\mathrm{Exec}}_B\ i_n$; as A obeys or answers $\underline{\mathrm{Comm}}^0_A\, i_n$, $\underline{\mathrm{EQuest}}^0_A\, i_n$ by a correct model or reply (either $D^0(R_{i_n}) \Rightarrow \underline{\mathrm{Exec}}^0_A\, i_n$ or $D^0(R_{i_n}) \Rightarrow \underline{\mathrm{Expl}}^0_A\, i_n$) so node i_n is correctly understood and thus marked understood by B. The process continues, the sprout of the conversation moving from node to node in $D^1(R)$, until the Nth occasion at which A ostends goal = aim = Head and gives a correct model or explanation of R (Head), as required to satisfy $< \underline{\mathrm{Comm}}^0 i_N,\ \underline{\mathrm{EQuest}}^0 i_N > \; = \; < \underline{\mathrm{Comm}}^0(\mathrm{Head}), \underline{\mathrm{EQuest}}^0(\mathrm{Head}) >$.

1.3.5. But, at this point, selections of aim and goal have (at some n less than N) given a correct explanation $\underline{\mathrm{Expl}}^1_A$(Head). Hence, if A correctly explains the topic relation R (Head) he also correctly understands it.

1.4 *Cooperative transactions.* If, at any stage, A is unable to obey a command or to answer a question then he may give restricted commands or ask restricted questions; namely, commands/questions that belong to the sprout of the conversation; that is, a command/question (on occasion n) which B is obeying or answering on the same occasion (Table 1).

These are transactions whereby A can obtain cooperative aid from B. The CET heuristic gives no gratuitous aid but does not restrict the cooperation obtainable.

1.4.1. By the rules just delineated B is commanded/questioned

TABLE 6.1
Cooperative transaction in a strict conversation governed by a CET heuristic: Indirect commands and questions $\underline{\mathrm{Req}}^1$ $\underline{\mathrm{Req}}^0$ $\underline{\mathrm{Enq}}^1$ $\underline{\mathrm{Enq}}^0$ are used by A to modify an accepted goal or subgoal (that is any goal or subgoal in workset) or any accepted aim. The evaluative statements are logically redundant since the same meaning is conveyed by the values of marker predicates in the main display (in particular, values of understood).

	Indirect commands from A to B	Indirect questions from A to B	Executions by B to A	Explanations by B for A	Evaluations by B of A's productions
L^1	$\underline{\mathrm{Req}}^1$ i (Qualified form is specific request $\underline{\mathrm{Req}}^1$ ji)	$\underline{\mathrm{Enq}}^1$ i (Qualified form is specific enquiry $\underline{\mathrm{Enq}}^1$ ji)	$\underline{\mathrm{Exec}}^1_B$ i (Possible methods of learning relation R_i)	$\underline{\mathrm{Expl}}^1_B$ i (Teaching strategy)	$\underline{\mathrm{Eval}}^1_B$ of A's strategy
L^0	$\underline{\mathrm{Req}}^0$ i (Qualified form is specific request $\underline{\mathrm{Req}}^0$ ji)	$\underline{\mathrm{Enq}}^0$ i (Qualified form is specific enquiry $\underline{\mathrm{Enq}}^0$ ji)	$\underline{\mathrm{Exec}}^0_B$ (Demonstration on the modelling facility)	$\underline{\mathrm{Expl}}^0_B$ i (Demonstrative explanation)	$\underline{\mathrm{Eval}}^0_B$ (Knowledge of results evaluation of A's explanation or model)

whenever A is, and produces $\underline{\mathrm{Exec}}^1_B$i, $\underline{\mathrm{Expl}}^1_B$i or $\underline{\mathrm{Exec}}^0_B$i, $\underline{\mathrm{Expl}}^0_B$i when/before A does so. Further, B explanations are correct since $\underline{\mathrm{Proc}}^1_B$ = Execution $D^1(R)$ and $\underline{\mathrm{Proc}}^0_B$i = Execution $D^0(R_i)$, for all R_i in R. For example, if CASTE acts in the conversational domain of probability theory the $\underline{\mathrm{Proc}}^1_B$ i are applications of all legitimate relational operators to those R_j entailed by R_i in R (Appendix K, data base); $\underline{\mathrm{Expl}}^1_B$i are the L-described productions. Further the $\underline{\mathrm{Proc}}^0_B$ i are specialisations or i parameterisations of the task structure routine in Appendix E (so that $\underline{\mathrm{Exec}}^0_B$i is a set of demonstrations of R_i and $\underline{\mathrm{Expl}}^0_B$i is a set of demonstrative explanations of R_i). In addition, the routine in Appendix E matches $\underline{\mathrm{Exec}}^0_A$ i to $\underline{\mathrm{Exec}}^0_B$ i, or $\underline{\mathrm{Expl}}^0_A$ i to $\underline{\mathrm{Expl}}^0_B$ i, to obtain a correctness signal that assigns the value of an understood marker to node i and furnishes knowledge of results with values correct and complete, or incomplete, or mistaken.

1.4.2. Thus B is in a position to cooperate with A since B carries out computations equivalent to all the computations A can legally carry out.

1.4.3. A's restricted commands are called $\underline{\mathrm{Req}}^0$ at level L^0 and $\underline{\mathrm{Req}}^1$ at level L^1 (namely *requests*).

1.4.4. A's restricted questions are called $\underline{\mathrm{Enq}}^0$ at level L^0 and $\underline{\mathrm{Enq}}^1$ at level L^1 (namely *enquiries*).

1.4.5. B cooperates with A as follows (Table 1):

B's *knowledge of results* statement is $\underline{\mathrm{EVal}}^0_B$i (an evaluation of either $\underline{\mathrm{Exec}}^0_A$i or $\underline{\mathrm{Expl}}^0_A$).

B's statements also include $\underline{\mathrm{EVal}}^1_B$ (an evaluation of $\underline{\mathrm{Expl}}^1_A$i) which is not currently employed.

B replies to $\underline{\mathrm{Req}}^0$i with a demonstration (one member of $\underline{\mathrm{Exec}}^0_B$i) on the modelling facility (for example, STATLAB).

B replies to $\underline{\mathrm{Req}}^1$i by (visually, on the entailment structure) advising B of the operations that could be used to derive R_i from the currently understood topic relations; that is, all of $\underline{\mathrm{Exec}}^1_B$i.

B replies to $\underline{\mathrm{Enq}}^1$i by all of $\underline{\mathrm{Expl}}^1_B$i (since $\underline{\mathrm{Exec}}^1_B$i is displayed within the L description, and since the display is a time/delay and time/intensity coded presentation able to exhibit the many possible paths as one pictorial image, $\underline{\mathrm{Exec}}^1_B$i is identical with $\underline{\mathrm{Expl}}^1_B$i; but this need not be the case and for some $D^1(R)$ it could not be the case).

B replies to $\underline{\mathrm{Enq}}^0$i by $\underline{\mathrm{Expl}}^0_B$i and by $\underline{\mathrm{EVal}}^0_B$i (the latter is redundant, since correct understanding illuminates a signal lamp, to mark R_i as understood and, for the CET heuristic, A must seek further cooperation if correct understanding is not reached).

1.5. *Characterisation of learning strategies.*

1.5.1. Since R(Head) is understood at occasion N, $\underline{\mathrm{Expl}}^1_A$(Head) is available at or before occasion N and is A's learning strategy (two different examples are shown, typical of a holist learner and a serialist learner, in Plate 6 and Plate 7 of Chapter 4).

1.5.1.1. Clearly for $n > 0$ but less than N, A's learning strategy up to n is available at or before occasion n.

1.5.1.2. If B never cooperated with A, this strategy would be uniquely one of A's L^1 procedures (his unique construction and

memory of his concept of R (Head)). By measure of B's cooperation, it is a hybrid belonging to the conversation rather than A only.

1.5.2. Since R (Head) is understood on occasion N, $\underline{\mathrm{Expl}}^0_A$(Head) is available at the end of occasion N. It is A's performance strategy.

1.5.2.1. Clearly, for $n > 0$ but less than N, A's performance strategy is available at the end of occasion n.

1.5.2.2. If B never cooperated with A, this strategy would be uniquely one of A's L^0 concepts of R (Head). By measure of B's cooperation, it is a hybrid belonging to the conversation rather than A only.

1.5.3. Since B is a CET heuristic, A receives as much co-operative assistance as he likes. But A must reach correct understanding, by furnishing pairs of correct explanations (further, these may not be copies of any demonstration he has received; there is a checking operation in the task structure routine of Appendix E that excludes this possibility). Hence, at least some of the learning strategy and of the performance strategy is due to A only.

In this sense, the CET heuristic minimally adulterates the "pure" learning of a student; it acts as a cognitive reflector that minimises the constraint whilst ensuring that all occasions belong to a strict conversation. The "amount of bias" introduced depends entirely upon the amount and kind of cooperation demanded by the student.

1.5.4. Any occasion n contains a (possibly identical) aim node and a set of goal nodes. As commonplace usage A appreciates the aim node topic relation (formally, he can give an L^1 description of it) though he is not, (unless the aim node is also the goal node) in a position to learn about it or understand it. The distance, in irredundant entailment arcs between the aim node and the goal node(s) on occasion n is thus called A's appreciation span on occasion n. The mean value of A's appreciation span over all occasion 0, 1, ... n, n+1, ... N in a strict conversation anchored by a CET heuristic on R, is A's appreciation span over the domain R, and is thus a parameter of A's learning strategy for R.

If A's appreciation span over R is non zero, then the learning strategy is holist; if it is zero, the learning strategy is serialist. Since, in practice, the differences are very large it is hardly necessary to qualify this comment by "substantially non zero" and "zero or nearly so".

1.5.5. If f = aim on occasion n then all nodes marked as understood in the workset (since these nodes stand for topic relations A may regard as properties) become A's coordinates of R_f. Hence, it is possible to compute the adicity of R_f as seen by A on occasion n and to subtract from it the minimal possible adicity of R_f (the number of nodes in one of the Im Ent Set ki of each goal i in workset or by way of a compromise measure, the average number. This calculation yields the apparent adicity of R_f, in R, for A and the mean value of this quantity over all occasions is A's mean apparent adicity and is a parameter of A's learning strategy for R. Empirically the values of apparent adicity for a given student on a given class of conversational domains do not overlap. If A's mean apparent adicity in R is large (greater than 3 or so), then A has a holist strategy in R; if this quantity is small (1 or fractionally greater), A has a serialist strategy in R.

1.5.6. For some human beings, acting in the role of A, the average value of mean apparent adicity in R, taken over CET regulated conversations on subject matters that have differently structured Rs, is fairly constant and is a useful index of their propensity to adopt a holist or a serialist learning strategy. It is not the only index and is confounded, in other human beings, by a factor of diversity; that is, an ability to change strategy to suit the subject matter. However, in the context of one R or one class of Rs, this characterisation as holistic or serialistic is dichotomous. Once a conversation has begun, cognitive fixity ensures that one or other kind of mental organisation will be established. Thereafter (if the organisation is holistic), any serialistic procedure is P/P incompatible (Chapter 5, Section 2.5.5.5) and is rejected.

Conversely (if the organisation is serialist) any holist procedure is P/P incompatible and is rejected.

1.5.7. The mean number of topic relations ostended in goal (or established in workset) is one (but neither the only nor the best) index of the number of loci of control accommodated by A's brain, regarded as an M Individual α inhabited by A; thus, of the L processor clocking number. Hence, the mean apparent adicity of A in α averaged over several conversational domains is one index,

though not the only one, of α's clocking number or the holist/serialist competence of A's brain.

2. Other Strict Conversations. The Uncertainty Regulation Heuristic

All other B heuristics are based upon the CET heuristic but involve the consideration of certain additional facilities and question forms (Table 2).

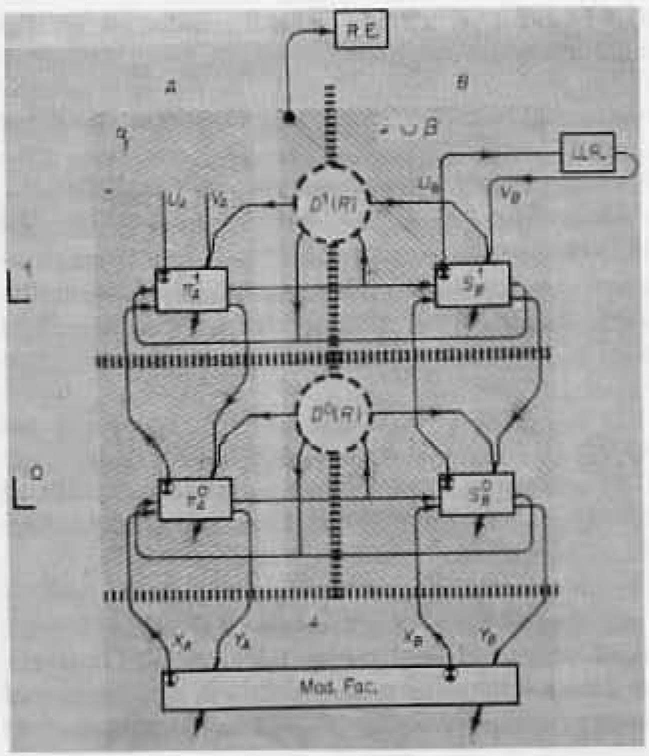
2.1. *Uncertainty regulation.* The uncertainty regulation (tutorial) heuristic discussed in Chapter 4 imposes boundary conditions upon the operation of a CET heuristic and is represented by Icon 10.

Values of A's uncertainty (H) and correct belief (θ) are computed in respect of each goal node and in respect of each aim node (H^*, θ^*), by a belief and opinion sampling system (BOSS of Chapter 4). These variables, their differences and gradients are used to control the degree of cooperation that B gives to A.

(a) By far the most important uncertainty regulation method depends upon equating the tutorial process to a learning strategy A is competent to execute. The strategy type and the student's competence are determined as early as possible in order to avoid the adverse effects of cognitive fixity (though the assignments are

TABLE 6.2
Transactions added to those used in instrumenting the CET heuristic in order to realise an uncertainty regulation heuristic in which the degree of co-operation given to A depends upon B's estimate of A's uncertainty and correct belief.
Uncertainties and correct beliefs are sampled (both at levels L^1 and L^0) through evaluative responses and confidence estimates in reply to PQuests.

	Problem posing questions for subgoal of node i or aim node i	Confidence estimates in reply to PQuests given subgoal of node i or aim of node i
L^1	$\underline{\text{PQuest}}_A^1\ i$ (For R_i = aim)	$\underline{\text{Eval}}_A^1\ i$ (For R_i = aim)
L^0	$\underline{\text{PQuest}}_A^0\ i$ (For R_i = subgoal)	$\underline{\text{Eval}}_A^0\ i$ (For R_i = subgoal)



Icon 10.

checked from time to time). Determination is achieved either by the operations described in Chapter 4, Section 7, or by one or more of the stronger criteria outlined in Section 1.5. As a result of this determination it may be necessary (Chapter 4, Section 7) to give the student advice about how to learn or even (in any more authoritarian form of tuition) to insist that he learns in a particular way.

The advice is displayed, usually, through the entailment structure inscribed at the interface and is generated by executing one or more $\underline{\text{Proc}}^1_B$i under the constraints imposed by Section 1.5.4 and Section 1.5.5, given an assignment of the student's learning strategy (as holist or serialist) and evidence that he is competent to execute it. In general, of course, the displayed advice is not uniquely valued. As noted in Chapter 4, Section 7, it is only possible to select one defensible path if special conditions are satisfied.

(b) Local optimisation is achieved (Chapter 4) by the provision of tutorial (cueing) data selected for subgoal = i from $\underline{\text{Expl}}^0_B$i. For this purpose there must be a value metric (a distance, in the sense of Chapter 2, or Banerji 1970, a series of evaluation sets) over demonstrations or their L^0 descriptions and the B heuristic provides more or less valuable data to maintain H and θ within limits.

(c) If there is no obvious metric the names of the demonstrations or demonstrative explanations $\underline{\text{Expl}}^0_B$j,i in $\underline{\text{Expl}}^0_B$j are displayed and A is allowed or required (for subgoal = i) to issue $\underline{\text{Req}}^0$j,i or $\underline{\text{Enq}}^0$j,i subject to the following constraint on occasion n. For each $\underline{\text{Req}}^0$ or $\underline{\text{Enq}}^0$ there is a unit cost. For each pair i,n there is a cash flow i,n that depends upon the predicted value of θ_i, and H_i. On occasion n, A has a cash balance that increases at a rate cash flow i,n from an initial value of zero. One unit cost is deducted from cash balance for each $\underline{\text{Req}}^0$ or $\underline{\text{Enq}}^0$ transaction and such transactions are prohibited unless cash balance is positive. Though not described in this book such valuation schemes have been widely employed (Pask and Von Foerster 1960, 1961; Pask 1960, 1961, 1966, 1969; Pask and Lewis 1964, 1969).

It remains (in the next section) to refine the notions of "multiple choice question" and "confidence estimate" both of which are employed in evaluating the macro grain variables H, θ, H*, θ* of Chapter 4, Section 7.

2.2 *L^0 PQuest transactions.* If you receive a command but are not allowed time in which to execute it rationally, then you guess; similarly, if you receive a command and do not have its execution precondition in your cognitive repertoire, then you also guess.

If you guess by selecting amongst some pre-specified collection of exclusive alternatives (or, in fact, any of Harrah's (1963) types of whether-question disjuncts) then by virtue of having been furnished with alternatives (or a description of them) the command becomes a question; in the simplest case a one-out-of-many or multiple choice question; but it may be any of the question forms based on exclusive disjuncts (for example, finite list questions).

Since alternatives, in this sense, are provided as part of any BOSS transaction, L does not contain "guess" commands. They are replaced by "selection" demanding questions called PQuests

(Table 2). A simple (multiple choice type) PQuest is answered by naming an alternative called Alter from a set called an AltSet such that one and only one Alter in AltSet is correct. Complex PQuests are not employed in the experiments so far discussed but may be synthesised, by iteration and selection, from simple PQuests.

There is a systematic method for constructing an AltSet i for all $PQuest^0_A$ i asked of R_i in R provided that all nodes in at least one ImEntSet k,i are marked as understood on the occasion when $PQuest^0_A$ i is presented. Under the CET heuristic (or any tutorial extrapolation) this condition ensures the existence, on occasion n, of $Proc^0_A$ j for each R_j of nodes indexed as members of ImEntSet i that are also marked understood. Thus A may regard the R_i as though they were properties related by R_i.

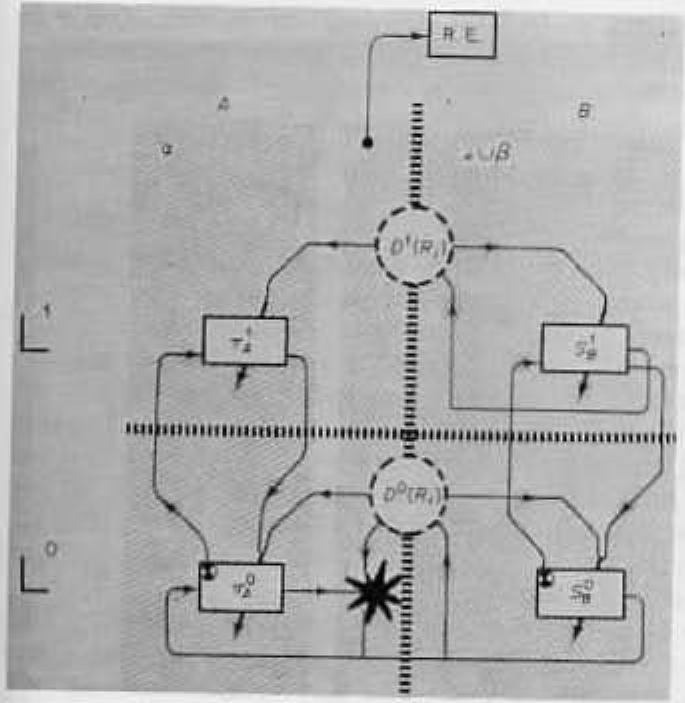
The construction method is described in Appendix I. It generates AltSet i that are classes of exclusive Alter i. Each Alter i is the value(s) of L^0 object variable(s) standing for elements of the sets that are regarded as though they were properties on this occasion. As a special, but interesting case, the Alter may designate values of variables or classes of states in the modelling facility. In either case, only one Alter or AltSet i satisfies R_i.

The commonest interpretation of a multiple choice question stems from mental test administration and carries the tacit assumption that the question is a stimulus, eliciting a selective response. This view is inadequate for the present purpose where, instead, $PQuest^0_A$ i is interpreted as a truncated form of $EQuest^0_A$ i, that is,

$$PQuest^0_A i \;=\; (EQuest^0_A i) \wedge (Altset\ i) \wedge (t \to 1)$$

or "Altset is provided and the clock is zeroed after one beat" (shown, pictorially in Icon 11).

In other words, $PQuest^0_A$ i poses a problem which A may or may not be able to solve. For each operation A performs the t index is incremented. Here A must output the name computed at $t = 1$, if it is a member of AltSet, or if not, he must guess the member of AltSet using the guess as one operation. According to this point of view, A, qua P Individual does not do any guesswork that is necessary. If he needs to guess, because no $Proc^0_A$ i exist, A consults an appropriate wheel of chance (in his brain or his environment) which selects the name of one Alter ϵ AltSet i. On the other hand, if no guessing is needed, A applies whatever $Proc^0$s



Icon 11.

exist in $Proc^0_A$ i, under the initial conditions prescribed by R_i and AltSet i, to yield one Alter by derivation (though not modelling, which would advance the t clock prematurely). If this derivation were actually spelled out, it would be one alternative statement in a multiple choice test "frame". A does not spell it out; he merely names an alter or points to its index (one modelling operation) as a result of which $t \to 1$ as required by the "clock-stopping" edict.

2.3. Sometimes the demand for a selection of some Alter ϵ Alter i is replaced by the requirement for a confidence estimate over the alternatives, that is, if $PQuest^0_A$ i has an AltSet i with m_i members (and recalling that one and only one Alter ϵ AltSet i is deemed R_i — satisfying or correct), then A must specify m_i numbers p_{ji}, $j = 1, \ldots m_i$ obeying the syntactic restriction that $1 \geqslant p_{ji} \geqslant 0$ (for all j) and that $\sum_j p_{ji} = 1$. The selective response (picking out one Alter) is isomorphic with the unique confidence estimate in which one p_{ji} is unity valued, and the rest of them are (as a syntactic necessity) zero valued.

Hence, a confidence estimate can yield all the data obtainable from a definitive choice and much more data under circumstances where A is in doubt. In particular, the unique confidence estimate setting all the $p_i = 1/m_i$ has the same interpretation as an unbiased guess.

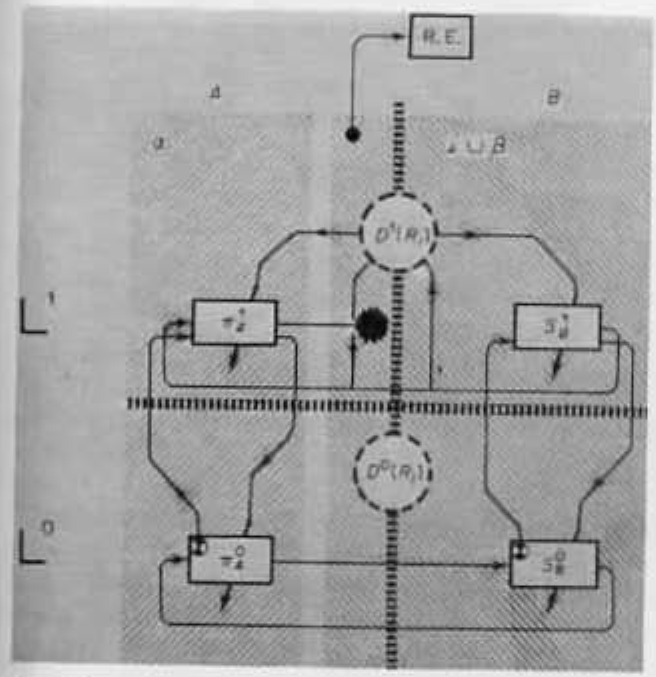
2.4. If A is required to select one Alter i ϵ Altset i at a single instant (perhaps of his own reckoning) and if A actually does so, it is still impossible (on this data alone) to distinguish the following cases. (a) A worked out a solution to the problem but was not allowed to reveal it; instead he selected the one and only one Alter indicated by his solution method when posed the requirement to compute the index of whichever Alter ϵ Alter i satisfies the known relation R_i. (b) A guessed. In complete ignorance of R_i and given only the Alt Set i, A employed some wheel of chance to select (on his behalf) just one of the Alter. (c) Cases (a) and (b) are combined, in the sense that part of the problem is solved by computation (for example, excluding certain Alter from consideration), the rest by guessing and selection.

Of course, A might be asked what he did (giving part of Expl^0_A i as his reply). But that is prohibited as "unobjective" in many contexts and is rejected in CASTE for quite a different reason (the uncertainty regulation heuristic needs to compute values of $H_i = \Sigma\, p_{ji} \log p_{ji}$ in order to act as it is designed to act).

In contrast, the confidence estimation format can, to some extent, distinguish between cases (a), (b), and (c); moreover, it delivers the required degree of belief values p_{ji} from which values of H (and the Shuford correct belief score θ) are calculated by the subsystem BOSS.

The reply to Proc^0_A i is thus taken as a confidence estimate which is a special case of an evaluation, EVal^0_A i (other cases are rank orderings and ratings along specified dimensions). Since the confidence estimate format is the only instance of EVal^0_A i in the CASTE experiments this term will not be qualified but the reserved symbol ("*" in Icon 11) stands for any L^0 evaluation.

2.5. Multiple choice questions at level L^1 (Icon 12) are built up, presented (through BOSS) and answered in the same manner. The simplest PQuest^1_A (again marked "*") is identical with PQuest^0_A i. Except that aim (node f) is substituted for subgoal (node i) and that no provisions are made with respect to the understanding markers of nodes in ImEntSet f; the construction of AltSet^1



Icon 12.

follows the method described in Appendix I. Hence, A is asked, by PQuest^1_A f to state his degree of belief that certain statements Alter ϵ AltSet f satisfy R_f.

If it happens that aim = subgoal (f = i) then PQuest^0_A i = PQuest^1_A i. Only one degree of belief distribution is supplied and only one pair of macro variables are evaluated; namely H and θ, as before. This case (which occurs quite often) is a degenerate instance of a PQuest^1_A f. So, (if aim = subgoal) no attempt is made to compute H^* and θ^*, the "look ahead" uncertainty and correct belief of Chapter 4, Section 7.

Otherwise, PQuest^1_A f is not degenerate. Strictly, it is asked of a description of R_i (namely $D^1(R_i)$) not of R_i itself. In particular, the Alter ϵ Alt Set f are nodes or classes of nodes in the entailment structure, which A can also describe because he understands the L^1 descriptors (guaranteed, amongst other things by the requirements placed upon Prim^1). So, in Appendix I, the Pred^{0}i may be replaced by the descriptors Pred^1 f of nodes in ImEntSet f.

A's reply is, as before, a confidence estimate Eval^1_A f from which the "look ahead" uncertainty and correct belief are calculated; H^* and θ^*).

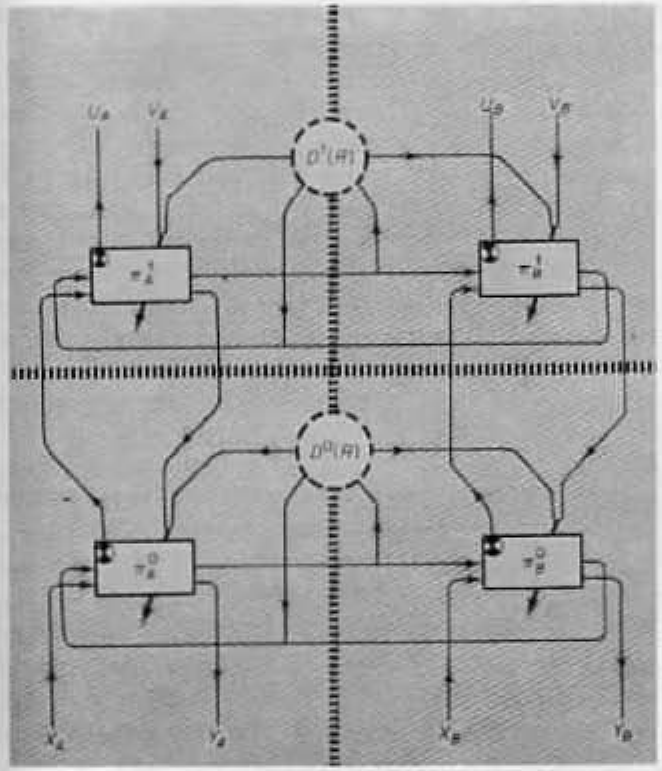
2.6. The categories PQuest^1 and EQuest^1 are by no means exhausted by the instances cited up to this point. For example, any exclusive classes of nodes (having an L^1 description in terms of the L^1 descriptors) can be Alter ϵ Alt Set i; any relation between these and other nodes can be the relation (call it R^*) to be satisfied. It is crucial, in this connection, to notice that A can ostend unit classes (for example, $< E, 2, i, \theta >$, in "CASTE") that are unoccupied by nodes. In fact he can point at an indefinite number of them. As B is programmed, such queries are met by a standard reply, "No Node", because A has agreed to restrict his domain to R. But this condition can and will be relaxed in moving from R to R(n), in Chapter 8.

3. Paradigms for experimental situations

Standard experimental situations are more restricted than CASTE transactions but less thoroughly controlled insofar as the conversation (if any) is not usually strict. There is nothing improper about this fact. Our submission in the matter is simply that "fostering good experimentation" implies (for human beings) an experimental contract of some sort within which the experimenter makes an attempt, often a successful one, to ensure that the actual dialogue approximates one of rather few strict forms or paradigms. Some of these forms are shown in the following icons, some in Chapter 9 and some in Chapter 11.

3.1. *Introspection (perjorative usage).* When "introspection" is derogated with reason, this is mostly because no effort is made to secure any kind of translatability (to anyone, participant experimenter, other respondent) or even the measure of translatability required to maintain self-consistent records. In brief, the experimental situation is sloppy. The comments in the next section take for granted a situation that is not carelessly contrived and highlight some of the difficulties that beset introspective and retrospective methods, even so.

3.2. *Introspection (unqualified).* Icon 13 represents a "conversation" taking place between two P Individuals (there could be more of them) executed in one M Individual, a brain.



Icon 13.

Quite possibly the P Individuals π_A and π_B figure as a learner and a teacher. If so, this icon gives substance to the earlier contention that whenever someone (identified as an M Individual) is said "to learn on his own", in particular, to direct his own attention, follow his bent or personal curiosity, or explore a domain, this statement implies the coexistence of at least two P Individuals π_A and π_B in the same brain.

More generally, the icon represents private thinking and cogitation. As an aside, if the M Individual is a non biological processor π_A and π_B correspond to a pure form of the "proposer" and "critic" subprogrammes of most mindlike artificial intelligence programmes.

As it stands, nothing can be said about A and B; if they were equipped with a modelling facility or environment (for example a room to explore) it would be possible to observe a "casting around behaviour" or the like (this case is discussed below). But it would not be possible, by this means, to examine the A, B dialogue.

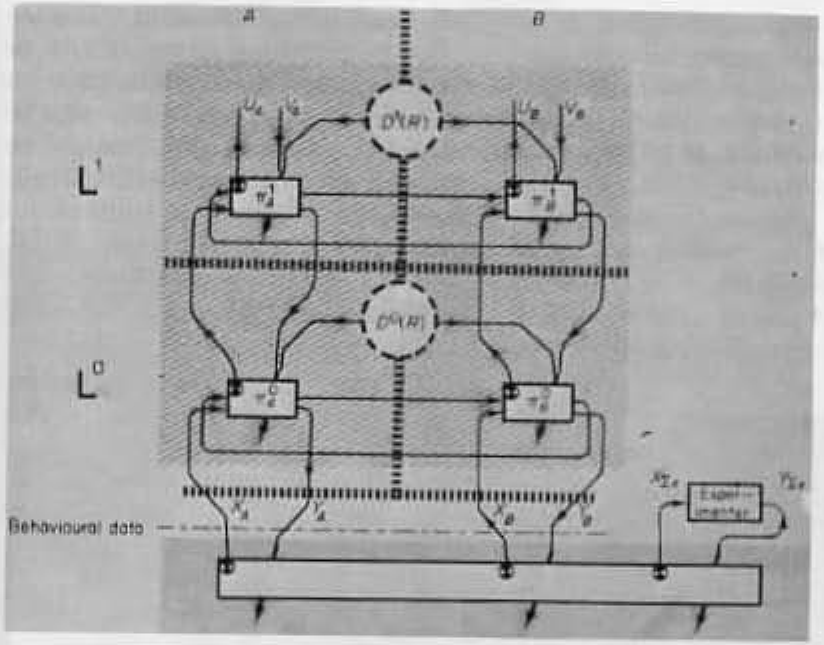
Several remedial expedients can be adopted. One of them, retrospection, involves setting up an interview like situation after the event and the interview technique (whereby retrospections are elicited) closely approximates the operation of a CET heuristic. The expedient is criticised on the grounds that a retrospective report is distorted. This may be so, but it is worth adding the qualification that the chief reason for distortion is not "forgetting" but an uncertainty over which of several P Individuals are addressed during the interview (or, as it were, which one is talking retrospectively).

The other main expedient, introspection using a protocol, meets with the objection that a reporting requirement impairs smooth flowing thought. Once again, that may be so. We only maintain that the special kind of protocol obtained by observing a CET conversation will maximise the data available by establishing a proper cleavage between A and B (ideally a support of A) located in a distinct processor. The distinct processor need not be mechanical. It can be a separate brain that executes a humanly manageable version of the CET heuristic. Notably, the "paired experiments" reported by Luria (1961) involve non mechanical CET operations. So, of course, does the Teachback method of Chapter 3. Mechanisation is a matter of convenience only.

3.3 *Behaviouristic experiments.* As argued in Chapter 1, rather few experiments really are completely behaviouristic. Nevertheless, it is useful to demarcate the restricted modes of observation possible if they were. Interestingly enough, the main restrictions also apply to those kinds of "cognitive" experiment in which the predicates and response forms are prescribed by the experimenter and all interactions with the respondent are causal interactions.

The constraints and possibilities are summarised by Icon 14 from which one of the causal couplings with the modelling facility (the "environment") can be omitted if desired. The single M Individual is the "organism". The icon can be made to accommodate group behaviour experiments, like Glasser's (1967) study, if two or more organisms (α and β, say) are distinguished.

The scope of behaviourism can be extended by adopting the following expedient. In consonance with the argument of Chapter 5, (the footnote to Section 1.7.1 and the discussion in Section



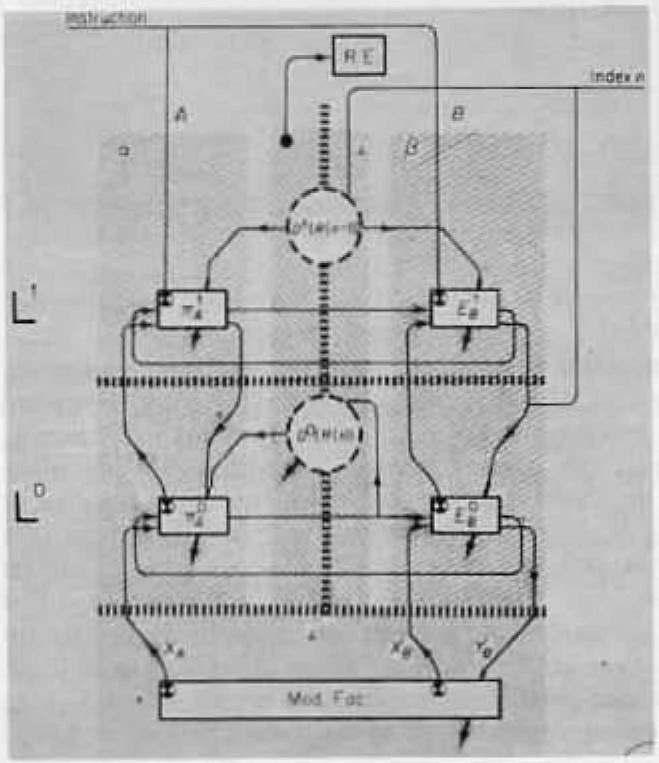
Icon 14.

2.5.8) the modelling facility, in Icon 14, may be legitimately interpreted as part of a P Individual's processor; "his" brain and body, (his M Individual) rather than "his" environment. Surely, the experimenter can observe interactions within this processor, for example, by inserting micro-electrodes to sample the flux of neural events. If so, his observations and his operations (the observer's description and parametric operations in Icon 14) are thus identified. But the result of adopting this expedient is obvious. The observations in question are physiological, not psychological. Even if the observer were in a position to iron out the complexities of parallel computation, he would still be looking at the physiological concomitants of mentation, not at mentation itself.

3.4 *Construct psychology.* As a prelude, rescind the restriction that participants are unable to predicate by acting upon ($D^1(R)$ or $D^0(R)$) inscribed at an interface. No outrageous licence is taken by doing so, since the restriction was imposed, arbitrarily, as a matter of convenience.

Operations that do act upon inscriptions at an interface are represented as parametric arrows, penetrating either $D^1(R)$ or $D^0(R)$ as the case may be. However, the operations in question modify the inscribed relations, as a result of which $D^1(R)$ must be rewritten as $D^1(R(n))$, if it is penetrated by a parametric arrow. Similarly, $D^0(R)$, if it is also effected, must be rewritten $D^0(R(n))$.

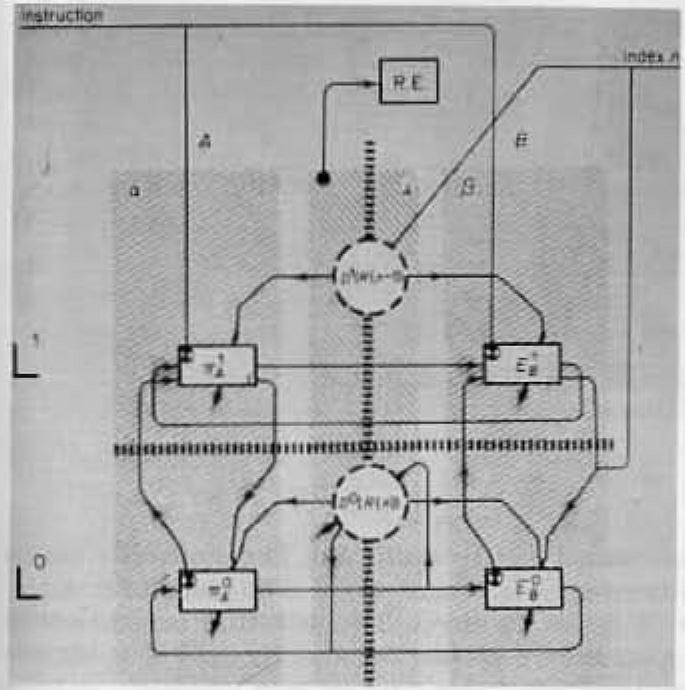
Personal constructs[15] (in Kelly's 1955 sense) are winkled out by a participant experimenter shown, henceforward, as E. According to the present theory, this experimenter, who may act in several modes (Icon 15, Icon 16 and Icon 17) approximates the strict conversation of an evolutionary CET heuristic.



Icon 15.

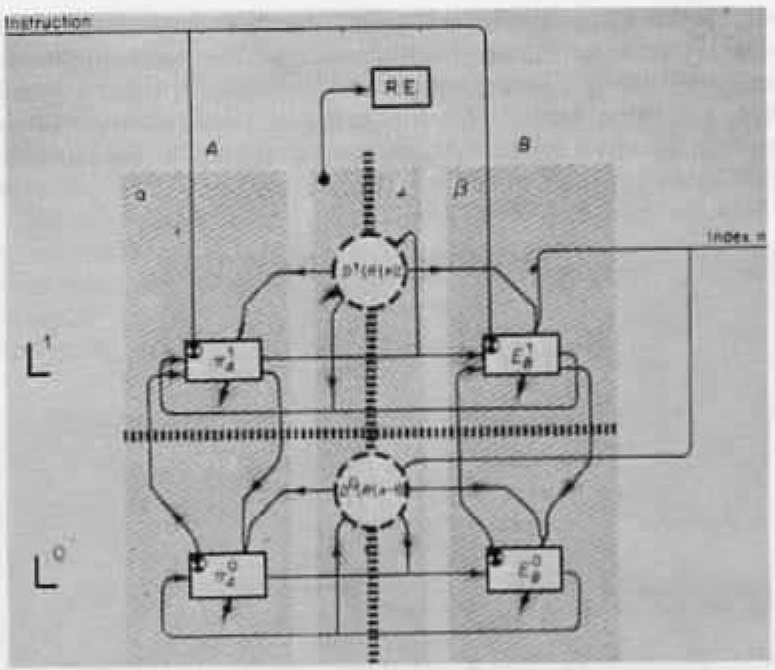
[15] Our concepts are probably equivalent to constructs; our memories to constructs of constructs; our "learning" either encompasses or is equivalent to "experimentation".

Icon 15 represents the repertory grid method. E presents triads of objects in a modelling facility and, at the same moment, indexes a yet to be filled in structure $D^0(R(n))$; $D^1(R(n-1))$ and $D^0(R(n-1))$ being given. The filling in, or predication, is an L description of a new relation (it may be a property, in the limit) as part of $D(R(n))$.



Icon 16.

Of the methods discussed by Bannister and Mair 1968 (also in Hinkle's (1964) thesis on laddering) there are two fundamental routes for further predication. One of them (subordination) gives constructs in terms of constructs of constructs (i.e. it yields $D^0(R(n))$ by a different route (Icon 16). The other method (superordination) is represented by Icon 17. It yields constructs of constructs (completing $D^1(R(n))$, using existing constructs as the "objects" and differs from Icon 15 insofar as the modelling facility is (one) t clocked, and (one) τ clocked, though the interface is not.



Icon 17.

3.5 *Recapitulation and generalisation.* The particulars can be entered into these icons in as much detail as desired. For example, though Icon 14 glosses the gamut of behaviouristic experiments in what may appear to be a cavalier fashion it is possible to retrieve the lot by systematically fixing constant each parametric connection Y or description X, in turn and repeating the process for pairs etc. Thereby, the limited modes of experimentation possible under this philosophical commitment are generated. It is true that a great deal of excellent "psychological" data has, in the process, been respectfully consigned to "neurophysiology" where, according to this point of view, it belongs.

Regarding genuine cognitive studies, the present theory is at odds with none of them; neither the perspicaciously eclectic approach of Bartlett (1932), nor the thoughtful functionalism of Treisman (1969), Broadbent (1957, 1971) and others, nor with the psychology of doubt and uncertainty as represented by Cohen (1964, 1970, 1972), nor the full blooded studies of human

cognition that spring from separate origins in the work of James (1890), Lewin (1936), and Bruner et al. (1956). It tallies, too, with the bases of Gestalt psychology (though not with their epiphenomenal interpretations). It provides a systemic account of the experimental paradigms underlying this work, which prove more sophisticated than they are often supposed to be.

The theory was presented quite deliberately in the limited arena of CASTE where each facet is open to critical appraisal. Insofar as the reader is (for all that) unconvinced about the reality of predication (the point of theory we found most difficult to assimilate) Icons 15, 16 and 17 give a practical, everyday (repertory grid administration) picture of the innovative name-giving that goes on in the evolutionary conversations to be described in Chapter 7 and Chapter 8. Perhaps the best way to come to terms with these ideas is to manipulate the icons or, if possible, to run the programs listed in Appendix D, Appendix E and (the course assembly heuristic) in Appendix K.